

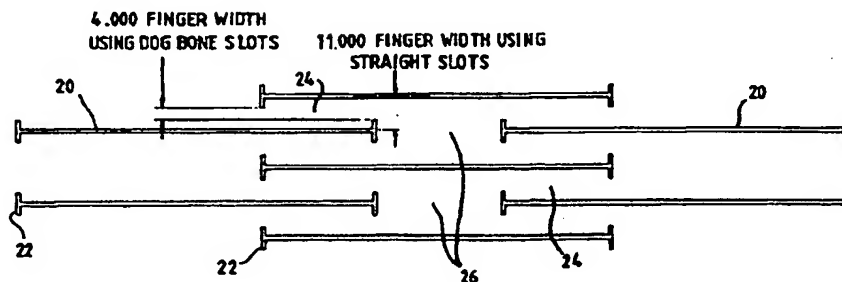
PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

| | | |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------|
| (51) International Patent Classification ⁶ : E21B 17/08 | A1 | (11) International Publication Number: WO 98/26152 (43) International Publication Date: 18 June 1998 (18.06.98) |
| (21) International Application Number: PCT/GB97/03450 (22) International Filing Date: 12 December 1997 (12.12.97) (30) Priority Data: 9625939.5 13 December 1996 (13.12.96) GB (71) Applicant (for all designated States except US): PETROLINE WELLSYSTEMS LIMITED [GB/GB]; Offshore Technol- ogy Park, Claymore Drive, Bridge of Don, Aberdeen AB23 8GD (GB). (72) Inventor; and (75) Inventor/Applicant (for US only): METCALFE, Paul, David [GB/GB]; North Wing, Bucklerburn Steading, Peterculter AB14 0NP (GB). (74) Agents: McCALLUM, William, Potter et al.; Cruikshank & Fairweather, 19 Royal Exchange Square, Glasgow G1 3AE (GB). | (81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, GW, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG). Published With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments. | |

(54) Title: EXPANDABLE TUBING



(57) Abstract

Expandable tubing, as utilised in downhole applications in the oil and gas exploration and extraction industries, comprises tubing having a multiplicity of overlapping longitudinally extending slots (20), the slots being wider at one or both end portions. Conveniently, the slot ends are widened by the provision of short transverse slots (22), to provide the slots with a "dog bone" appearance.

BEST AVAILABLE COPY

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

| | | | | | | | |
|----|--------------------------|----|---------------------------------------|----|-------------------------------------------|----|--------------------------|
| AL | Albania | ES | Spain | LS | Lesotho | SI | Slovenia |
| AM | Armenia | FI | Finland | LT | Lithuania | SK | Slovakia |
| AT | Austria | FR | France | LU | Luxembourg | SN | Senegal |
| AU | Australia | GA | Gabon | LV | Latvia | SZ | Swaziland |
| AZ | Azerbaijan | GB | United Kingdom | MC | Monaco | TD | Chad |
| BA | Bosnia and Herzegovina | GE | Georgia | MD | Republic of Moldova | TG | Togo |
| BB | Barbados | GH | Ghana | MG | Madagascar | TJ | Tajikistan |
| BE | Belgium | GN | Guinea | MK | The former Yugoslav Republic of Macedonia | TM | Turkmenistan |
| BF | Burkina Faso | GR | Greece | ML | Mali | TR | Turkey |
| BG | Bulgaria | HU | Hungary | MN | Mongolia | TT | Trinidad and Tobago |
| BJ | Benin | IE | Ireland | MR | Mauritania | UA | Ukraine |
| BR | Brazil | IL | Israel | MW | Malawi | UG | Uganda |
| BY | Belarus | IS | Iceland | MX | Mexico | US | United States of America |
| CA | Canada | IT | Italy | NE | Niger | UZ | Uzbekistan |
| CF | Central African Republic | JP | Japan | NL | Netherlands | VN | Viet Nam |
| CG | Congo | KE | Kenya | NO | Norway | YU | Yugoslavia |
| CH | Switzerland | KG | Kyrgyzstan | NZ | New Zealand | ZW | Zimbabwe |
| CI | Côte d'Ivoire | KP | Democratic People's Republic of Korea | PL | Poland | | |
| CM | Cameroon | KR | Republic of Korea | PT | Portugal | | |
| CN | China | KZ | Kazakhstan | RO | Romania | | |
| CU | Cuba | LC | Saint Lucia | RU | Russian Federation | | |
| CZ | Czech Republic | LI | Liechtenstein | SD | Sudan | | |
| DE | Germany | LK | Sri Lanka | SE | Sweden | | |
| DK | Denmark | LR | Liberia | SG | Singapore | | |
| EE | Estonia | | | | | | |

EXPANDABLE TUBING

This invention relates to expandable tubing comprising tubing have a multiplicity of overlapping longitudinally extending slots therein. In particular, but not exclusively, the invention relates to expandable tubing as
5 utilised in downhole applications in the oil and gas exploration and extraction industries, such as the tubing sold under the EST trademark by the applicants.

WO93\25800 (Shell Internationale Research) discloses a tubing comprising lengths of tube which have been
10 machined to create a large number of overlapping longitudinal slots. The tube may be expanded radially outwardly by running a mandrel through the tubing.

The magnitude of the force necessary to expand the tubing is related to the number of slots in the tubing,
15 that is the fewer the number of slots the greater the expanding force. Further, expandable tubing provided with relatively few slots is more prone to fracture and catastrophic failure of the tubing during expansion. However, forming a large number of slots in a section of
20 tubing weakens the tubing and renders the tubing more susceptible to damage during handling and running into the borehole.

It is among the objectives of embodiments of the present invention to obviate or mitigate these
25 difficulties.

According to the present invention there is provided

expandable tubing comprising tubing having a multiplicity of overlapping longitudinally extending slots therein, at least some of the slots being wider at one or both slot end portions.

5 Surprisingly, it has been found that increasing the width of the slot ends, without increasing the width of the remainder of the slot, reduces the force required to expand the tubing without reducing the strength of the tubing to any significant degree. Without wishing to be bound by
10 theory, it is believed that the force necessary to expand a section of tubing is a function of the width of the "finger" between adjacent overlapping slots; by enlarging the slot ends, the effective width of the finger is reduced to the circumferential spacing between the adjacent
15 enlarged slot ends.

Preferably, each slot is wider at both ends.

Preferably also, a majority of the slots in the tubing are wider at one or both end portions.

Preferably also, the wider slot end portions are
20 symmetrical about the respective longitudinal slot axis. Conveniently, the slot end portions are widened by provision of transverse slots at the slot ends, although other slot or recess forms, such as round holes, at or adjacent the slot ends, may be utilised. Such widening of
25 the slot ends provides slots with a "dog bone" appearance.

As used herein, the term slot is intended to encompass any cutting, machining or weakening of the tubing intended to facilitate radial expansion, including slots which

extend only partially through the tubing and which permit the remaining thinned sections to fracture or extend.

This and other aspects of the present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a sectional view of a length of prior art expandable tubing, shown in an expanded configuration;

Figure 2 is a sectional view on line 2 - 2 of Figure 1 and also shows the prior art tubing in unexpanded configuration; and

Figure 3 is a view of a portion of the wall of expandable tubing in accordance with a preferred embodiment of the present invention.

Reference is first made to Figures 1 and 2 of the drawings, which illustrate a length of conventional expandable slotted tubing 10. In its initially unexpanded configuration, the tubing 10 is simply a length of pipe in which a series of longitudinal slots 12 have been machined (shown as tube 10a with slots 12a in Figure 2). Applying radially outward force to the tubing wall, for example by passing a mandrel through the tubing, causes the tube to expand such that the slots 12a become diamond-shaped openings 12b, as described in WO93\25800.

Reference is now made to Figure 3 of the drawings, which illustrates a section of tubing wall in accordance with a preferred embodiment of the present invention. The tubing wall defines a series of longitudinal slots 20, each having shorter transverse slots 22 at the ends thereof. In

this particular example the slots 20 are 115 mm long, whereas the transverse slots 22 are 8 mm long. The area of tubing between adjacent overlapping slots is known as a finger 24, whereas the areas between the ends of aligned slots 20, which areas are generally subject to negligible deformation during expansion, are known as nodes 26.

Testing has revealed that the magnitude of force necessary to expand a section of tubing is related to the width of the fingers 24 between the overlapping slot ends. In the example illustrated in Figure 3, if the transverse slots 22 were not provided, the finger width between the slots 20 would be 11 mm. However, the provision of the transverse slots 22 reduces the effective width of the fingers 24 to only 4 mm, substantially reducing the magnitude of force which is necessary to expand the tubing. Surprisingly, it has been found that providing such transverse slots does not result in a significant decrease in the strength of the slotted tubing.

It will be clear to those of skill in the art that the above-described embodiment is merely exemplary of the present invention, and that modifications and improvements may be made thereto without departing from the scope of the invention.

CLAIMS

1. Expandable tubing comprising tubing having a multiplicity of overlapping longitudinally extending slots therein, at least some of the slots being wider at one or both slot end portions.
5
2. The tubing of claim 1, wherein each slot is wider at both ends.
3. The tubing of claim 1 or 2, wherein a majority of the slots in the tubing are wider at least one end portion.
- 10 4. The tubing of claim 1, 2 or 3, wherein the wider slot end portions are symmetrical about the respective longitudinal slot axis.
5. The tubing of any of the preceding claims wherein the wider slot end portions include transverse slots at the
15 slot ends.

1/2

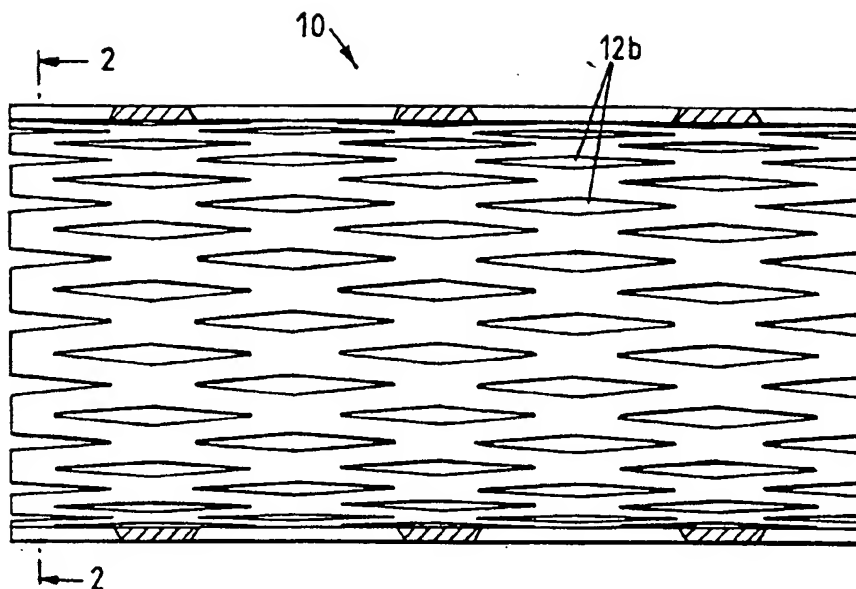


FIG. 1
(PRIOR ART)

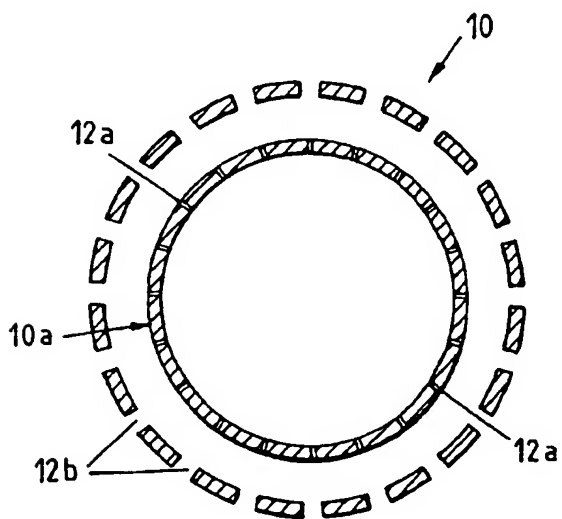
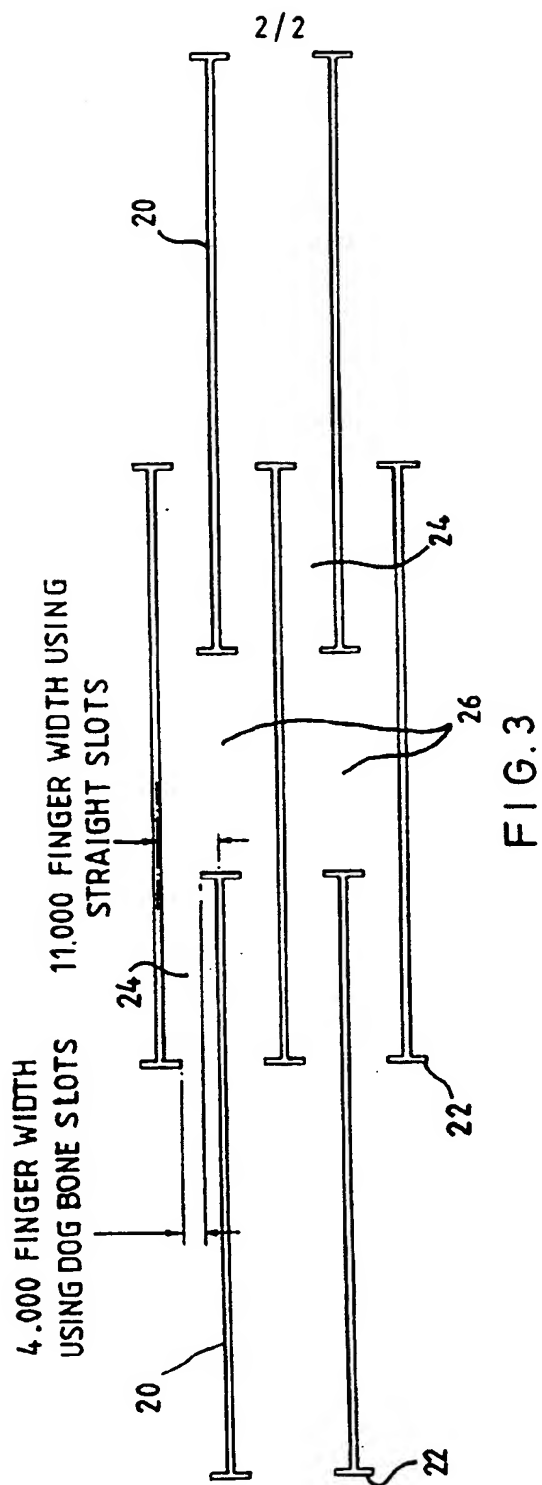


FIG. 2
(PRIOR ART)

SUBSTITUTE SHEET (RULE 26)



INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 97/03450

A. CLASSIFICATION OF SUBJECT MATTER

E 21 B 17/08

According to International Patent Classification (IPC) or to both national classification and IPC ⁶

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E 21 B, F 16 L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|------------|-------------------------------------------------------------------------------------------------------------------------|-----------------------|
| X | US 4349050 A (BERGSTROM et al.) 14 September 1982 (14.09.82), fig. 2, claims. --- | 1-4 |
| A | WO 96/37681 A1 (PETROLINE WIRELINE SERVICES LIMITED) 28 November 1996 (28.11.96), the whole document. -- | 1 |
| A | US 2633374 A (BOICE) 31 March 1953 (31.03.53), the whole document. ----- | 1 |

☐ Further documents are listed in the continuation of box C.

☐ Patent family members are listed in annex.

* Special categories of cited documents:

- *A* document defining the general state of the art which is not considered to be of particular relevance
- *E* earlier document but published on or after the international filing date
- *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- *O* document referring to an oral disclosure, use, exhibition or other means
- *P* document published prior to the international filing date but later than the priority date claimed

- *T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- *Z* document member of the same patent family

Date of the actual completion of the international search
20 March 1998

Date of mailing of the international search report
17.04.98

Name and mailing address of the ISA

European Patent Office, P.O. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+ 31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+ 31-70) 340-3016

Authorized officer

WANKMÜLLER e.h.

ANHANG

zum Internationalen Recherchen-
bericht über die internationale
Patentanmeldung Nr.

ANNEX

to the International Search
Report to the International Patent
Application No.

ANNEXE

au rapport de recherche Inter-
national relatif à la demande de brevet
international n°

PCT/GB 97/03450 SAE 179001

In diesem Anhang sind die Mitglieder
der Patentfamilien der im obenge-
nannten Internationalen Recherchenbericht
angeführten Patentdokumente angegeben.
Diese Angaben dienen nur zur Unter-
richtung und erfolgen ohne Gewähr.

This Annex lists the patent family
members relating to the patent documents
cited in the above-mentioned inter-
national search report. The Office is
in no way liable for these particulars
which are given merely for the purpose
of information.

La présente annexe indique les
membres de la famille de brevets
relatifs aux documents de brevets cités
dans le rapport de recherche Inter-
national visée ci-dessus. Les renseigne-
ments fournis sont donnés à titre indica-
tif et n'engagent pas la responsabilité
de l'Office.

| In Recherchenbericht angeführtes Patentdokument Patent document cited in search report Document de brevet cité dans le rapport de recherche | Datum der Veröffentlichung Publication date Date de publication | Mitglied(er) der Patentfamilie Patent family member(s) Membre(s) de la famille de brevets | Datum der Veröffentlichung Publication date Date de publication |
|------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|
| US A 4349050 | 14-09-82 | keine - none - rien | |
| WD A1 9637681 | 28-11-96 | AU A1 58265/96 AU A1 73493/96 EP A1 824628 EP A1 828918 GB A0 9510465 NO A0 975348 NO A0 975350 WO A1 9637680 | 11-12-96 11-12-96 25-02-98 18-03-98 19-07-95 21-11-97 21-11-97 28-11-96 |
| US A 2633374 | | keine - none - rien | |

**This Page is Inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record**

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ **BLACK BORDERS**
- ☐ **IMAGE CUT OFF AT TOP, BOTTOM OR SIDES**
- ☒ **FADED TEXT OR DRAWING**
- ☒ **BLURRED OR ILLEGIBLE TEXT OR DRAWING**
- ☐ **SKEWED/SLANTED IMAGES**
- ☐ **COLOR OR BLACK AND WHITE PHOTOGRAPHS**
- ☐ **GRAY SCALE DOCUMENTS**
- ☐ **LINES OR MARKS ON ORIGINAL DOCUMENT**
- ☒ **REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY**
- ☐ **OTHER:** _____

IMAGES ARE BEST AVAILABLE COPY.

As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.